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LIFE CYCLE COST ANALYSIS CHANGES MIXED WASTE TREATMENT PROGRAM AT THE SAVANNAH RIVER SITE (U)

by J. B. Pickett

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

Other Authors:

J. L. England
H. L. Martin

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Life Cycle Cost Analysis Changes Mixed Waste Treatment Program at the Savannah River Site

John B. Pickett, Ph.D.

Jeffery L. England

H. L. (Lee) Martin

Westinghouse Savannah River Co.

Aiken, South Carolina

ABSTRACT

Recent changes in the world political situation have caused major changes in the entire DOE weapons complex. A direct result of the reduced need for weapons production has been a re-evaluation of the treatment projects for mixed (hazardous/radioactive) wastes generated from metal finishing and plating operations and from a mixed waste incinerator at the Savannah River Site (SRS). A Life Cycle Cost (LCC) analysis was conducted for two waste treatment projects to determine the most cost effective approach in response to SRS mission changes. A key parameter included in the LCC analysis was the cost of the disposal vaults required for the final stabilized wasteform(s). The analysis indicated that volume reduction of the final stabilized wasteform(s) can provide significant cost savings. The LCC analysis demonstrated that one SRS project could be eliminated, and a second project could be totally "rescoped and downsized". The changes resulted in an estimated Life Cycle Cost saving (over a 20 year period) of $270,000,000.

INTRODUCTION

A LCC analysis approach was used to determine the most cost effective way to respond to changing requirements for the Department of Energy's weapons programs. Plutonium production for nuclear weapons is not currently forecast, due to the change in the world geopolitical situation and the phase down of the nuclear arsenal. A major hazardous/radioactive (mixed) waste treatment facility was scheduled for construction at the Savannah River Site in 1994. The facility was the "M-Area Waste Disposal Facility" (better known as "Y - Area") and its initial mission (as defined in 1984) was to treat and dispose of low-level radioactive waste from nickel plating operations in the Reactor Materials Department (M-Area). An additional waste stream, liquid blowdown from the on-site Consolidated Incinerator Facility (CIF), was subsequently added to the scope of Y-Area in 1987.

With the elimination of new plutonium production at the SRS, new nickel plating waste was eliminated, such that only the plating waste sludge stored from previous plutonium target production needed to be treated. A cost analysis determined that the stored waste could be treated much more cost effectively in a one-time campaign by a hazardous waste treatment sub-contractor. This called into question whether it would then be cost effective to use the Y-Area facility only for the remaining waste stream (CIF blowdown).

A broad based task team composed of personnel from the WSRC production, Engineering departments, and the Savannah River Technology Center (SRTC) could identify no other high volume, liquid mixed waste stream(s) that would be suitable for the Y-Area facility. The task team also determined that a 60-75% volume reduction of the final wasteform from the CIF blowdown could be achieved by evaporation, wastewater treatment, and/or vitrification. A Life Cycle Cost analyses showed that an estimated savings of $270,000,000 over a twenty year period could be obtained by:

- changing the scope of the Y-Area facility from a high throughput centralized waste treatment facility to one close-coupled to the CIF, utilizing volume reduction of the final wasteform; and
- treating the stored M-Area sludge by a sub-contractor in a one time campaign.

BACKGROUND

The "M-Area Waste Disposal Facility" ("Y-Area") was originally conceived in 1984 to stabilize and dispose of the wastewater treatment sludge (an F006 listed waste) from the nickel plating line operations in M-Area. The wastewater treatment sludge resulted from the nickel plating of depleted uranium cores, which were subsequently encased in aluminum containers (or cans). The depleted uranium targets were irradiated in the SRS reactors, with the subsequent nuclear transmutation of uranium-238 to plutonium-239. The Pu-239 was chemically separated from the uranium target, and utilized for weapons production.

At one time in the mid-1980's, the M-Area wastewater treatment sludge was being generated at a rate of approximately 40,000 gallons/month (~500,000 gals. per year). The Y-Area facility was designed to have a 1,200,000 gallon per year effective capacity, and since it would not be on-line sooner than 1993/1994, it would therefore have to work-off the 3 to 4 million gallons of stored sludge (in addition to on-going M-Area waste generation). The Y-Area facility design assumed that the same treatment concept developed for SRS non-hazardous low-level radioactive waste stream would be used, which was cementatious stabilization using a blast furnace slag (BFS) / flyash (FA) /Portland cement mixture. This treatment process is currently in use, in the SRS "Z-Area" facility. The key difference between the Y and Z-Area facilities was that Y-Area would require a hazardous waste treatment and disposal permit under the Resource Conservation and Recovery Act (RCRA) Sub-Title C regulations. The Z-Area facility does not treat "listed" hazardous wastes, and is therefore operated under a Industrial Wastewater Treatment permit. The new Y-Area was to be constructed adjacent to the existing Z-Area, and would have utilized the BFS/FA/cement storage silos as a common feed. The M-Area sludge and the CIF blowdown were to be mixed with the dry solids at about a 50/50 ratio, and the resulting grout would be pumped directly to a RCRA disposal vault(s).

Initial Leaching Studies on Stabilized M-Area Sludge

Bench scale treatability studies were conducted on the M-Area sludge in 1988 to support a "delisting petition" for the stabilized sludge. The Y-Area/Z-Area formulation of 50% BFS/FA/cement and 50% sludge was used to prepare the stabilized samples. The Toxicity Characteristic Leaching Procedure (TCLP) leaching results on the stabilized samples indicated that the initially proposed (Y-Area) formulation would not meet the "Best Developed Available Technology" (BDAT) stabilization criteria for Metal Finishing Industry wastes. The BDAT standards were promulgated by the Environmental Protection Agency (EPA) in August, 1988 as a part of the Land Disposal Restrictions (LDR). The M-Area sludge had TCLP leachant results for nickel ranging from 0.03 to 0.81 mg/L, vs. the LDR criteria for F006 wastes of a maximum of 0.32 mg/L.

Leaching Studies on Pretreated/Stabilized Sludge

In 1989 the WSRC Reactor Materials Engineering Department (RMET) and the Savannah River Technology Center (SRTC) developed and demonstrated a new process that would allow the final M-Area sludge wasteform from Y-Area to meet the BDAT leaching criteria for nickel. The process included pressure filtration and pre-rinsing of the sludge to remove the high levels of sodium nitrate (~30% dry weight). The resulting filtered sludge could be reslurried, mixed with either BFS/FA/Portland cement (or with Portland cement alone), to provide a final wasteform that would meet the LDR criteria for nickel. The capital cost estimate for the pretreatment facility, to be constructed in M-Area, was $12 million.

M-AREA ALTERNATIVE COST STUDY

To determine the most cost effective approach for the treatment, stabilization, and final disposal of the plating line sludges stored in M-Area, a Life Cycle Cost analysis was conducted by the WSRC Systems Engineering Department. The economic study assumed that no additional plating line sludges due to plutonium target production would be generated. It also assumed that a total inventory of approximately 500,000 gallons of stored sludge would need to be treated in 1994 (vs. the original estimate of 3-4 million gallons), with a work-off period of 10 years. Three cases were studied:

A. The sludges were pretreated in M-Area, reslurried, shipped to Y-Area, stabilized with BFS/FA/Portland cement, and disposed in the Y-Area vaults.

B. The sludges are pretreated <u>and</u> stabilized in M-Area, and then shipped to the Hazardous Waste/Mixed Waste (HW/MW) vaults for disposal. This case also assumed a 75% volume reduction for the final wasteform vs. case No. 1, by adding Portland cement to the sludge prior to the high pressure filtration step. (This volume reduction technique was defined during the 1989 RMET/SRTC bench scale studies mentioned above). Disposal in the HW/MW vaults is more expensive on a per cubic foot basis (vs. the Y-Area vault), due to the higher cost of the HW/MW vaults ($ 6 million vs. $ 4 million) and a lower loading factor (drums vs. full pour of grout).

C. The third case assumed that a hazardous waste subcontractor would stabilize the sludge in M-Area, place in containers, and dispose in the HW/MW vaults. A 2X volume increase from sludge to final cementatious wasteform was assumed in this case.

The results of the M-Area alternative cost study are summarized below:

Case	A	B	C
	Pretreat in M-Area, stabilize & dispose in Y-Area	Pretreat and stabilize in M-Area; dispose to HW/MW vaults	Contractor stabilize in M-Area; dispose to HW/MW vaults
	$\$ \times 10^6$		
Life Cycle Cost	67.7	46.4	24.2
Present Worth Cost	53.6	37.7	18.0

The Life Cycle and Present Worth Cost estimates for Case A included the capital and operating costs for the M-Area pretreatment facility, a prorated operating cost at Y-Area, and the capital cost for the Y-Area vaults. The cost saving in Case B vs. Case A resulted from the lower volume of final waste (even including the higher cost of the HW/MW vaults and the lower loading factor) and no operating cost for Y-Area to treat M-Area sludge. The contractor option (Case C) indicated a significant opportunity for an additional $20 million cast saving (vs. case B). The cost saving for this option resulted primarily from eliminating the capital cost for the pretreatment facility in M-Area ($12 million), and eliminating the operating costs for the pretreatment facility over the 10 year work-off period ($2 million/year).

Based on this cost study, WSRC recommended to the Department of Energy that the contractor option be selected, and that the M-Area wastes not be shipped to and treated/disposed in Y-Area. However, this recommendation caused the justification for the entire Y-Area project to be questioned, since the volume of CIF blowdown (250,000 gallons/year) to be treated at Y-Area was only a fraction of its rated capacity (1,200,000 gals. per year).

Y-AREA ALTERNATIVES STUDY

Alternative Treatment Systems

A broad based WSRC task team was formed to evaluate the most cost effective treatment and disposal options for the SRS liquid mixed wastes. The team determined that the only low level liquid radioactive/hazardous (mixed) waste streams that were likely to be generated at the Savannah River Site (and treated at the Y-Area facility) were the M-Area sludge and the CIF blowdown. A number of other possible streams were considered, but the volumes were low (< 100,000 gals. per year) and the characteristics of the potential streams were not well defined. The team concluded that these streams would be amenable to in-situ treatment, rather than centralized treatment, if in fact they ever materialized. The team utilized the results of the M-Area cost study, and included a number of alternative treatment systems for the CIF blowdown in the cost analysis. The treatment alternatives for the SRS liquid mixed wastes are summarized below:

1. CIF Blowdown Wastewater Treatment

   The CIF blowdown will be recirculated to concentrate the sodium chloride and ash to the optimum levels for the CIF operation (~10% NaCl/4% ash) resulting in a basis of 250,000 gallons/year of blowdown. The blowdown would be treated by conventional wastewater treatment techniques, including precipitation, settling, UV treatment (to inhibit bacterial formation), filtration, and reverse osmosis. The treated effluent would be released via an NPDES permit, and the sludge from the WWT would be stabilized using an existing stabilization system for the CIF ash solids.

2. CIF Unrecirculated Blowdown/Wastewater Treatment

   The CIF blowdown would not be recirculated, resulting in a basis of 750,000 gallons per year. The blowdown would not be prefiltered in the recirculated case, resulting in a higher ash loading, but a lower total sodium chloride concentration. The blowdown would be treated by conventional wastewater treatment techniques, such as precipitation, settling, UV treatment, filtration, and reverse osmosis. The treated effluent would be released via an NPDES permit, and the sludge from the WWT would be stabilized using an existing stabilization system for the CIF ash solids.

The wastewater treatment options provide the lowest amount of final CIF blowdown sludge to be stabilized and disposed, due to the discharge of the treated effluent, which includes the soluble sodium chloride.

3. CIF Blowdown Evaporation/Sulfur Cement Stabilization

The CIF blowdown (250,000 gallons/year) would be evaporated until dry. The resulting material would be stabilized using a sulfur cement (due to the high sodium chloride content). The blowdown evaporator condensate would be recycled to the CIF scrubber or quench systems.

4. Cement Stabilization by Vendor

In this case the CIF blowdown would be stabilized directly, with no initial volume reduction due to water removal. A 2x volume increase is assumed for cementatious stabilization. The treatment equipment would be purchased by SRS, but operated by sub-contract personnel familiar with the process. There would be no liquid effluents.

5. Bitumen Stabilization by Vendor.

This Case is similar to Case No. 4, except that an asphalt binder system is used, rather than cement. In this case the CIF blowdown would be pre-evaporated, to allow the most economical asphalt stabilization. The treatment equipment would be purchased by SRS, but operated by sub-contract personnel familiar with the process. The evaporator condensate would be recycled to the CIF scrubber or quench systems.

6. Vitrification of the CIF Blowdown

In this Case, the blowdown would be pre-evaporated, and the resulting slurry (~50/50 water/solids) would be vitrified. The evaporator overheads would be recycled. The condensate from the vitrification unit, including the chloride as a volatile acid, would be treated with ion exchange resins to remove volatile metallic constituents such as cesium, strontium, mercury, etc. The treated effluent would be released via an NPDES outfall. The vitrification option would result in the lowest total volume of final stabilized wasteform to be disposed to the HW/MW vaults (~75-80% volume reduction vs. the original blowdown volume).

7. Y-Area Treatment and Disposal of CIF Blowdown and Pretreated M-Area Sludge

This case is the base case comparison, and includes the capital cost for Y-Area ($37 million), the capital cost for the M-Area Pretreatment ($12 million), $10 million annual operating costs for the two facilities, and $4 million per Y-Area vault. The capital cost estimate was adjusted for the $6 million previously spent on Title I design for the Y-Area project and the first vault (included in the Y-Area project). This case assumes a 2X volume increase for the stabilized wasteform vs. the initial CIF and M-Area waste volumes.

8. Y-Area Treats CIF Blowdown and M-Area Sludge (Without M-Area Pretreatment)

This case is the same as Case No. 7, except that it is assumed that a formulation will be developed which will eliminate the need to pretreat the sludge in M-Area (and therefore eliminate the capital and operating cost of the M-Area Pretreatment facility).

9. M-Area Subcontractor Treatment and Disposal to HW/MW Vaults

This is the same option discussed previously (Case C above), except that the cost estimate was increased in the Y-Area Alternative Study by $4 million to provide an interim storage facility for the stabilized M-Area waste (The HW/MW vaults would not be ready in time for direct transfer from the vendor treatment to the final disposal vault).

Life Cycle Cost Analysis Procedure

General Assumptions

- HW/MW vaults cost $6 million each
- HW/MW vaults will hold 9000 fifty-five gallon (or seventy-one gallon square) drums each
- HW/MW vaults will hold 1200 B-25's (90 cu. ft./B-25)
- Y-Area vaults cost $4 million each, with capacity of 180,000 cu. ft.
- Average labor rate = $44.50/hr.

- Start-up costs = 25% of 1st year operating cost + 5% of capital cost.
- Life cycle and present worth costs based on 20 year operating life, with no salvage value.
- The economic analysis is intended to compare the relative costs of the different cases, and is not intended to be a definitive cost estimate of the actual life cycle cost.
- The equipment specified for each option is essentially off-the-shelf, with a minimum of engineering modifications.
- All final wasteform(s) will meet the Land Disposal Restrictions TCLP leaching criteria.
- Stabilization of the sludges (cement, sulfur cement, asphalt) will result in 2X volume increase.
- Wastewater treatment will provide effluents which will meet NPDES permit requirements.

Economic Evaluation Analysis Method

The Life Cycle Cost (LCC) and Present Worth (PW) were calculated using the following definitions and formulae(1):

- LCC estimating is anticipated costs directly and indirectly related to preoperational, operational, and terminal stages.
- PW is a discounted dollar value, based on a technique of converting various cash flows occurring over a long period of time to equivalent amounts at a common point in time -- to facilitate a valid comparison.

- $LCC = (CC + SU) + (ECF \times Y)$

- $PW = (CC + SU) + (Y \times \{ [\frac{(1+i)^{N-1}}{(i \times (1+i)^{N})}] + D\})$

CC = Capital Cost)

SU = Start-Up cost

ECF = Escalated Cost Factor for 20 years = 29.5

Y = Yearly operating cost

N = Number of operating years (20)

i = Discount rate (5%)

D = operating cost escalation gradient factor (4.925)

Y-Area Alternative Cost Analysis Results

The Life Cycle Cost (LCC) and Present Worth (PW) results for the Y-Area alternatives economic study are summarized in Table 1

Table 1

Comparison of LCC and PW Costs for the Y-Area Alternatives

Case	$ X 10^6 PW	$ X 10^6 LCC
1. CIF Blowdown Wastewater Treatment	13.2	104
2. CIF Unrecirculated Blowdown/Wastewater Treatment	25.5	215
3. CIF Blowdown Evaporation/Sulfur Cement Stabilization	14.4	84
4. Cement Stabilization of CIF Blowdown by Vendor	13	286
5. Bitumen Stabilization of CIF Blowdown by Vendor	20.1	94
6. Vitrification of the CIF Blowdown	46.3	171
7. Y-Area Treatment and Disposal of CIF Blowdown and Pretreated M-Area Sludge (Base case)	46.6	385
8. Y-Area Treatment and Disposal of CIF Blowdown and M-Area Sludge (without pretreatment)	37	329
9. M-Area Subcontractor Treatment and Disposal to HW/MW Vaults	26	32

Summary

The most cost effective alternative was:

Evaporation of CIF blowdown:	$40 M PW / $84 M LCC
M-Area subcontrator:	+ $26 M PW / $32 M LCC
	= $66 M PW / $116 M LCC

Compared to the base case: $46 M PW / $385 M LCC (M = million)

The PW calculation is primarily based on the initial capital investment and startup costs of the facilities, while the LCC includes the continuing capital expenditures for the disposal vaults as operating expenses. It is the author's opinion that the LCC analysis provides a better comparison of the relative long term costs of the various cases than the PW calculation. This is due to the fact that the cost savings due to volume reduction of the final wasteform (building fewer disposal vaults) is more apparent in the LCC approach.

The combination of utilizing evaporation to volume reduce the CIF blowdown prior to stabilization, and utilizing a sub-contractor to stabilize the M-Area sludge (eliminating the pretreatment facility in M-Area) resulted in an estimated LCC saving of $270,000,000. The new approach was recommended to the Department of Energy-Savannah River Office (DOE-SR) by WSRC in September, 1991. The DOE-SR approved the recommendation, and immediately halted design activities on the Y-Area project.

LAND DISPOSAL RESTRICTIONS - FEDERAL FACILITIES COMPLIANCE AGREEMENT (LDR-FFCA) MODIFICATIONS

There was another hurdle to be overcome before the new SRS program could be implemented. The M-Area sludge is a RCRA listed waste and a portion of the sludge was a "California List" waste, since it had been "actively managed" after July 1987, and had a concentration of 134 mg/L in the liquid from the sludge. The DOE-SR and WSRC had negotiated a Land Disposal Restrictions - Federal Facilities Compliance Agreement with the Environmental Protection Agency-Region IV in January 1991. The LDR-FFCA between the DOE and the EPA specified a number of activities which would be conducted by specific dates. The specific activities included submission of complete permit applications for Y-Area facility and the M-Area Pretreatment Facility. Construction of both facilities within specific time periods after the permits were approved was specified in the FFCA, and treatment goals were to be defined when operations commenced. The existing LDR-FFCA therefore had to be modified to remove the Y-Area and M-Area Pretreatment facility permit and construction deadlines, and replace them with new goals for the vendor treatment.

The EPA approved the LDR-FFCA modification request in April 1992, mainly because the new vendor treatment approach allowed the treatment of the M-Area sludge to start about one year sooner than the original Y-Area concept, and treatment of the M-Area sludge would be completed approximately ten years sooner.

CONCLUSION

Changes in the mission of the DOE weapons complex from weapons production to environmental remediation activities requires that all of the preconceptions of the cold-war era be re-examined. With the end of the plutonium target production at the Savannah River Site, the need for a centralized waste treatment facility was re-evaluated. It was concluded that the centralized facility (Y-Area) could be replaced by a one time campaign by a sub-contractor to treat the M-Area sludge, and by a scaled down treatment facility for the CIF blowdown, which would include volume reduction to minimize the cost of long term mixed waste disposal. A Life Cycle Cost analysis indicated that the cost saving from the new approach could result in an estimated $270,000,000 saving over a period of 20 years.

This change in the SRS program to treat and dispose of hazardous/ radioactive wastes at the Savannah River Site exemplifies the commitment of the Westinghouse Savannah River Co. to provide the most cost effective management possible for the DOE challenges of the 90's.

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